(19) OAPI

ORGANISATION AFRICAINE DE LA PROPRIETE INTELLECTUELLE

(51) **Inter. Cl.**[8] **B60H 1/00 (06.01)**

(11) **N° 17247**

FASCICULE DE BREVET D'INVENTION

(21) **Numéro de dépôt : 1201500011**
(PCT/IB13/055748)

(22) **Date de dépôt : 12/07/2013**

(30) **Priorité (s) :**

IN n° 2027/MUM/2012 du 13/07/2012

(24) **Délivré le : 30/09/2015**

(45) **Publié le : 20.04.2016**

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(54) **Titre : Automotive cabin environment management system.**

(57) **Abrégé :**

The present disclosure provides an automotive cabin environment management system comprising : an enclosure, first air filer mounted on top of the enclosure, one or more air conditioning unit mounted within enclosure. The one or more air conditioning unit receives atmospheric air via the first air filter to generate conditioned air to be supplied to a cabin of the vehicle. A plurality of second air filters are mounted below the enclosure, wherein each of the plurality of second air filters are located on either sides of the first air filter and are fluidly communicably attached to one of the one or more air conditioning unit. Further, a plurality of connecting ducts are provided in the system for recirculating the air. At least one motorized flap is mounted within the plurality of connecting ducts to direct the air flow from roof ducts into the evaporative heat exchangers in severe mode of operation.

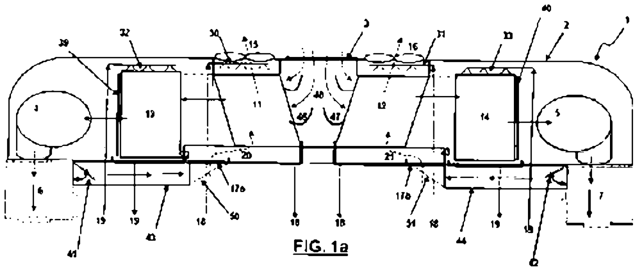


FIG. 1a

AUTOMOTIVE CABIN ENVIRONMENT MANAGEMENT SYSTEM

TECHNICAL FIELD

Embodiments of the disclosure relates to an air conditioning system. More particularly embodiments of the disclosure relates to an improved evaporative cooling system of a vehicle.

BACKGROUND OF DISCLOSURE

Conventional automotive AC systems works on vapour compression refrigeration cycle where HFC (R134) is used as refrigerant. Higher Global warming Potential (GWP) of R134a gas leading to higher operating costs and higher emissions, which are the major challenges in HFC based AC system.

Packaging of compressor and integrating the drive system is also critical and tedious in most of the cases. Performance of these types of systems deteriorates especially in lower vehicle speeds (city traffic) as the compressor is driven by the engine. In many situations, AC runs in recirculation mode which is also harmful for occupants travelling for prolonged time and long distances.

Cabin cooling system which works on a two stage indirect-direct evaporative cooling principle could be a solution to overcome these challenges.

Indirect – direct evaporative cooling uses air-to-air heat exchanger to remove heat from the primary air stream without adding moisture. In one stage, hot dry outside air is passed through a series of horizontal tubes that are wetted on the outside. A secondary air stream blows over the outside of the coils and exhausts the warm, moist air to the atmosphere. The atmospheric air is cooled without adding moisture as it passes through the tubes.

Indirect cooling is often paired with a second direct evaporative cooling stage, to cool the supply air further while adding some moisture to the supply air. Such two-stage systems can meet the entire cooling load for many vehicles run in hot and dry climates.

Two stage evaporative cooling systems provide cooler supply air at a lower relative humidity than direct evaporative coolers. The first indirect stage cools the supply air without increasing humidity.

Since the air is cooled, it has a reduced capacity to hold moisture. The air is then passed through a direct stage, which cools the air further while adding moisture.

Further, the use of direct-indirect evaporative cooling system in a vehicle is known in the art. The conventional direct-indirect evaporative cooling systems do not function efficiently in hot soak condition of the vehicle cabin. The term hot soak condition used herein above is defined as the condition under which the temperature within the vehicle cabin is more than the ambient temperature. The inefficient operation of conventional direct-indirect evaporative cooling systems causes passenger discomfort inside the vehicle cabin in the hot soak condition.

In light of the foregoing discussion, it is necessary to develop an improved direct and indirect evaporative air cooling system to overcome the limitations stated above.

SUMMARY OF THE DISCLOSURE

The shortcomings of the prior art are overcome and additional advantages are provided through the provision as claimed in the present disclosure. Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein and are considered a part of the claimed disclosure.

In an embodiment of the disclosure an automotive cabin environment management system comprising: an enclosure, a first air filter mounted on top of the enclosure, wherein the first air filter is configured to draw atmospheric air. One or more air conditioning unit mounted within the enclosure, wherein the one or more air conditioning unit receives atmospheric air via the first air filter to generate conditioned air to be supplied to a cabin of the vehicle. A plurality of second air filters are mounted below the enclosure, wherein each of the plurality of second air filters are located on either sides of the first air filter and are fluidly communicably attached to one of the one or more air conditioning unit. Further, a plurality of connecting ducts are provided in the system, wherein each of the plurality of connecting ducts are connected to at least one of the plurality of second air filters. At least one motorized flaps are mounted within the each of the plurality of connecting ducts, wherein the motorized flaps are located away from the plurality of the second air filters; wherein the plurality of second air filter, plurality of connecting ducts and at least one motorized flaps are arranged such that, the plurality of connecting ducts redirects predetermined volume of the conditioned air to be supplied to the cabin back into the one or more air conditioning unit via the plurality of second air filters when the motorized flaps are in operating condition.

In an embodiment of the disclosure each of the one or more air conditioning unit comprises: one or more evaporative heat exchangers of predetermined shape, wherein the one or more evaporative heat exchangers are configured in vicinity of the first air filter to receive atmospheric air via the first air filter. One or more evaporative pads are provided in the air conditioning unit, wherein the at least one evaporative pad is placed adjacent to one or more evaporative heat exchangers and is configured to receive substantially conditioned air from the one or more evaporative heat exchangers. One or more blowers are placed adjacent to the one or more evaporative pads, wherein the one or more blowers are configured to receive conditioned air from the one or more evaporative pads and supply the conditioned air into the cabin. At least one exhaust fan placed above each of the one or more evaporative heat exchangers, wherein the at least one exhaust fan expels hot air from the cabin to the atmosphere. Further, at least one water dispenser placed above the each of the one or more evaporative heat exchangers and the each of the one or more evaporative pads, wherein the at least one water dispenser is configured to dispense water onto the each of the one or more evaporative heat exchangers and the each of the one or more evaporative pads; at least one water eliminator placed adjacent to the each of the one or more evaporative pads, wherein at least one water eliminator configured to eliminate the moisture from the conditioned air.

In an embodiment of the disclosure plurality of air guiders located inside the each of the one or more air conditioning unit, wherein the plurality of air guiders are configured to guide the atmospheric air received via the first air filter into the one or more evaporative heat exchangers.

In an embodiment of the disclosure plurality of roof ducts connected to the enclosure, wherein the plurality of roof ducts runs through substantial length of the cabin for supplying conditioned air.

In an embodiment of the disclosure a first water sump is provided below the cabin of the vehicle adopted to store water, wherein the one or more evaporative heat exchangers of the one or more air conditioning unit receives water from the first water sump.

In an embodiment of the disclosure a second water sump is provided below the cabin of the vehicle adopted to store water, wherein the one or more evaporative pads of the one or more air conditioning unit receives water from the second water sump.

In an embodiment of the disclosure plurality of conduits are provided at the bottom of each of the one or more evaporative heat exchangers and the one or more evaporative pads within the enclosure for recirculating the water into the first water sump and second water sump.

In another non-limiting embodiment of the disclosure there is provided a method of managing an automotive cabin environment. The method comprising steps of: receiving atmospheric air into an one or more air conditioning unit mounted within the enclosure via a first air filter for conditioning the atmospheric air. Then, redirecting predetermined volume of the conditioned air to be supplied to the cabin of the vehicle back to the one or more air conditioning unit with the help of plurality of connecting ducts, wherein the conditioned air is redirected via plurality of second air filters into the one or more air conditioning unit for further conditioning; wherein, conditioned air is redirected when at least one motorized flap configured within the plurality of connecting ducts is in operating condition.

In an embodiment of the disclosure the at least one motorized flap is operated when the temperature of the cabin is more than predetermined cabin temperature.

In an embodiment of the disclosure the predetermined cabin temperature ranges from 25° C to 35°C.

The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The disclosure itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following description of an illustrative embodiment when read in conjunction with the accompanying figures. One or more embodiments are now described, by way of example only, with reference to the accompanying figures wherein like reference numerals represent like elements and in which:

FIG. 1a illustrates a longitudinal cross-sectional view of the Air conditioning unit according to an embodiment of the present invention.

Fig. 1b illustrates sectional views of the air conditioning unit showing the flap operations in normal and severe modes.

FIG. 2 illustrates a top view of the air conditioning unit shown in FIG. 1a.

FIG. 3 illustrates a side view of the vehicle showing the schematic layout of water distribution system connecting the automotive cabin environment management system and ducting arrangement.

FIG. 4a illustrates a rear view of the automobile layout shown in FIG. 3 and positioning of the plurality of vents on the plurality of roof ducts.

FIG. 4b illustrates a schematic layout of refrigerant circuit used in the disclosure.

FIG. 5 illustrates a front sectional view of indirect evaporative heat exchanger and an isometric view of heat exchanger plate construction.

FIG. 6 illustrates a conventional Psychrometric chart showing the thermodynamic processes of primary air stream in indirect cooling stage and direct cooling stage.

FIGS. 7a & 7b illustrates front sectional views of different heat exchanger configurations and vertical type indirect heat exchanger construction used in the disclosure.

FIGS. 8 & 9 are Flow charts illustrating Control logic for Motorized Flap operation and Control Logic for switching on the Blowers.

DETAILED DESCRIPTION

The foregoing has broadly outlined the features and technical advantages of the present disclosure in order that the description of the disclosure that follows may be better understood. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present disclosure. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the disclosure. The novel features which are believed to be characteristic of the disclosure, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present disclosure. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and make part of this disclosure.

An automobile/vehicle referred hereinabove and below can be a vehicle where the need of such cabin environment management system is necessary. For example, the vehicle is selected from group comprising but not limited to fuel cell automobiles including, but are not limited to bus, trucks, cars, electric powered vehicles, solar powered vehicles, fuel powered vehicles, ships, submarines, trains and the like.

FIG. 1a illustrates a longitudinal cross-sectional view of the air conditioning unit (1) such as but not limiting to direct and indirect evaporative air cooling system according to an embodiment of the present disclosure. The one or more air conditioning unit (1) is mounted within an enclosure (2), which is ideally mounted on top of the roof of a vehicle (49). The top of the enclosure (2) is fitted with a first air filter (3) through which the atmospheric air is drawn into the one or more air conditioning unit (1). The one or more air conditioning unit (1) consists of one or more evaporative heat exchangers (11, 12) of predetermined shape which are placed on either side of the first air filter (3). The one or more air conditioning unit (1) also consists of one or more evaporative pads (13, 14) placed adjacent to each of the one or more evaporative heat exchangers (11, 12). The one or more air conditioning unit (1) equipped within the enclosure (2) which has an open area just below the first air filter (3). Further, pluralities of air guiders (46, 47) are fixed to the inside of the enclosure (2) in such a manner so as to direct the atmospheric air onto the one or more evaporative heat exchangers (11, 12). The one or more evaporative pads (13, 14) which are placed adjacent to the each of the one or more evaporative heat exchangers (11, 12) receive the partially conditioned air from the one or more evaporative heat exchangers (11, 12) for further conditioning.

The one or more air conditioning unit (1) is further connected to plurality of roof ducts (6, 7) which are mounted inside the cabin (10) of the vehicle (49). The plurality of roof ducts (6, 7) are further provided with multiple numbers of vents (8, 9) to supply conditioned air to the cabin (10). The one or more blowers (4, 5) placed on either side of the air conditioning unit (1) are used to supply the conditioned air into the cabin (10), also since there are multiple number of compact sized one or more blowers (4, 5) on either side of the air conditioning unit (1) the vehicle (49), uniform air flows into the roof ducts (6, 7). Hence, this ensures uniform air distribution to the entire vehicle cabin (10) for the same cooling capacity requirement.

The one or more blowers (4, 5) mounted on each side of the air conditioning unit (1) draws the air from atmosphere through the first air filter (3) and passes via the one or more evaporative heat exchangers (11, 12) and one or more evaporative pads (13, 14). As the atmospheric air passes via the one or more evaporative heat exchangers (11, 12) and one or more evaporative pads (13, 14), the temperature of the atmospheric air is gradually reduced to less than ambient temperature and then supplied into the cabin (10) of the vehicle (49) through the roof ducts (6, 7) and vents (8, 9) respectively.

The opening area of the first air filter (3) varies from 1.5 to 2 times of total supply air openings at the one or more blower (4, 5) outlets on either side of the air conditioning unit (1).

In an embodiment of the present disclosure, the one or more blowers (4, 5) operate at different speeds with a DC supply voltage from battery system of the vehicle (49). The variable speed operation of the one or more blowers (4, 5) improves average energy efficiency of the one or more air conditioning unit (1) by operating at the lowest speed required by the cooling load unlike conventional auxiliary drive arrangement of belt, pulley and variable motor drive system for the blowers. The speed of the one or more blowers (4, 5) is varied by varying the input power to the blower motors by means of variable resistor which is in-built in the motors. Further, each blower motor is protected from water ingress and dust ingress by using compatible IP grade components, unlike conventional large sized metallic blower casing and impellers, the compact blowers are made with plastic materials.

Ambient atmospheric air is filtered in the first air filter (3) to supply clean and fresh air which passes vertically downwards initially and then redirected horizontally to the roof ducts (6, 7) and vents (8, 9). The one or more air conditioning unit (1) with the aid of plurality of air guiders (46, 47) helps in directing the air effectively to the one or more evaporative heat exchangers (11, 12).

The suction space (48) available between first air filter (3) and the one or more evaporative heat exchangers (11, 12) in the present disclosure is more than the conventional systems by about 20% due to trapezoidal construction of the one or more evaporative heat exchangers (11, 12) and its integrated orientation. There will be a reduction of 10% of blower noise when compared with conventional vertical type of one or more evaporative heat exchangers construction. Different type of heat exchanger configurations used in the present disclosure for indirect evaporative cooling stage is illustrated in Fig. 7. Further, vertical type indirect heat exchanger construction which can also be used for small cooling load requirements is illustrated in in Fig. 7b.

The redirected primary air enters into the one or more evaporative heat exchangers (11, 12) to undergo indirect evaporative cooling stage where it is cooled without the addition of moisture thereto. The cooled primary airflow leaves the indirect cooling stage and enters the one or more evaporative pads (13, 14) where it further undergoes direct evaporative cooling and the conditioned air is supplied to the cabin (10) of the vehicle (49). The secondary air flow from the cabin which serves to cool the primary air flow is directed to the bottom of the one or more evaporative heat exchangers (11, 12) through individual plurality of second air filters (17a, 17b). The secondary air flow from the cabin enters the bottom of the one or more evaporative heat exchangers (11, 12) through the plurality of second air filters (17a, 17b) which flows vertically or inclined in the indirect cooling stages and then exits to the atmosphere by means of multiple number of exhaust fans (15, 16) placed above the one or more evaporative heat exchangers (11, 12). 100% of second air filter areas are exposed to the passenger cabin air in normal operation of the air conditioning unit and 100% of secondary air filter areas are exposed to the primary air with the help of at least one motorized flaps (41, 42, 50, 51) and plurality of connecting ducts (43, 44).

During normal operating condition, the plurality of second air filters (17a, 17b) serve for the air coming from the cabin (10) of the vehicle (49). During hot soak or severe operating condition, the plurality of second air filters (17a, 17b) serves to pre-cool the primary air by passing partial cold air from the roof ducts (6, 7) into vertical channels of the one or more evaporative heat exchangers (11, 12).

In the present disclosure, there are two separate liquid storage sumps, namely first water sump (18) to supply water to the one or more evaporative heat exchangers (11, 12) for indirect evaporative cooling stage and second water sump (19) supplies water to the one or more evaporative pads (13, 14) for direct evaporative cooling. The first water sump (18) and the second water sump (19) are installed under the cabin floor (34) of the vehicle (49) at a level of accessibility to service.

FIGs 3, 4a and 4b, illustrates second water sump (19) mounted at a slightly higher position than the first water sump (18) and both are connected with a pipe to allow the water from the second water sump (19) to the first water sump (18). Further, a manual valve (56) and a float (57) arrangement are provided inside the first water sump (18) to allow certain amount of water from the second water sump (19) whenever required. Manual valve (56) is normally closed valve and this can be operated manually whenever there is a deficit of water in the first water sump (18). Otherwise these two water sumps are independent in regular operation.

There are four individual auxiliary sumps (20, 21, 22, 23) provided with sloping walls in the enclosure (2) of the air conditioning unit (1) to facilitate water drainage from the one or more evaporative heat exchangers and one or more evaporative pads (11, 12 and 13, 14) during cooling stages and then returned to the water sumps (18, 19). The first water sump (18) serves as a water reservoir for the one or more evaporative heat exchangers (11, 12) in indirect cooling stages and water is circulated through water filter (24), recirculating pump (28), water dispenser (30, 31) auxiliary sumps (20, 21) water filter (25) which are in turn connected with the flexible water pipes. Further, the first water sump (18) is also connected with a refrigerant circuit to cool the water inside the sump and supply chilled water to the one or more evaporative heat exchangers (11, 12) during indirect cooling stages.

Further, the second water sump (19) serves as a water reservoir for the one or more evaporative pads (13, 14) during direct cooling stages and water is circulated through water filter (26), recirculating pump (29), water dispensers (32, 33), auxiliary sumps (22, 23), water filter (27) which are in turn connected with the flexible water pipes. The pump (28) feeds the water at top portion of the one or more evaporative heat exchangers (11, 12) during the indirect cooling stages for the wet passages through the water dispensers (30, 31). Water returned from the auxiliary sumps (20, 21) is circulated down to the first water sump (18) through the water filter (25). The pump (29) feeds the water at top portion of the one or more evaporative pads (13, 14) during direct cooling stages through the water distributors (32, 33). Water returned from the auxiliary sumps (22, 23) is circulated down to the second water sump (19) through the water filter (27).

FIG. 5 illustrates a cross sectional view of the heat exchanger arrangement of the indirect cooling stages shown in FIG.1a. The one or more evaporative heat exchangers (11, 12) are mirror images in construction which are mounted on the Left Hand (LH) and Right Hand (RH) side of the one or more air conditioning unit (1). The indirect stage heat exchanger is divided into a first set of passages (36) for the primary air flow from the atmosphere, and second set of passages (37) for the secondary air from cabin (10). Second set of passages (37) are treated with non-woven material to enhance wettability. Water is conveyed by water dispenser (30, 31) in inclined or vertical direction in the secondary passages (37) to wet the surfaces of the heat exchanger plates (38). Secondary air from the cabin (10) flows through the secondary passages (37) and evaporatively cools the secondary heat exchanger plates (35). Meanwhile, the primary airflow travelling through the first set of passages (36) is cooled by contact with the surfaces of the cooled heat exchange plates (35). Primary air flow is cooled in this manner without adding any moisture which is known as sensible cooling. The sensibly cooled primary air leaves the one or more evaporative heat exchangers (11, 12) during the indirect cooling stages and is further cooled in the one or more evaporative pads (13, 14) during the direct cooling stages. The direct evaporative cooling stage includes an evaporative medium which includes a wetted pad or permeable medium, to evaporatively cool the primary air flow.

Referring back to FIG. 1a, which illustrates auxiliary sumps (20, 21, 22, 23) are positioned slightly inclined approximately at an angle 5° to ensure the drained water from indirect and direct cooling stages are directed to the respective first and second water sumps (18, 19). At least one water eliminators (39, 40) provided after the direct cooling stages to eliminate the water droplets before passing to the one or more blowers (4, 5) and then to roof ducts (6, 7).

FIG. 4a illustrates the rear view of roof duct and vents arrangement. The outlets on the air conditioning unit (1) are connected to the roof ducts (6, 7) respectively. One or more blowers (4, 5) throws the cold air to the roof ducts (6, 7) and then to the cabin (10) by the multiple number of vents (8, 9).

FIG. 3 illustrates side view of the duct arrangement inside the vehicle (49). The air conditioning unit (1) is mounted at the centre of the vehicle (49). The outlets of the air conditioning unit (1) are connected to the roof ducts (6, 7) which are mounted along the vehicle (49). The cold air from one or more blowers (4, 5) passes into the ducts vertically downwards then distributed to the front and rear sides of the duct. Air vents (8, 9) are mounted at the bottom and side of both roof ducts (6, 7) to supply cold air to the passenger cabin (10). Further the vents (8, 9) are not provided at sides, where the cabin (10) secondary air is exhausted to the atmosphere to avoid cold air short circuiting.

As shown in FIG. 1a, there are connecting duct arrangements (43, 44) between the roof ducts (6, 7) and plurality of second air filters (17a, 17b) which are exposed till the length of the second air filters zone. Two motorized flap arrangements (41, 42) are provided on the duct ends and another two motorized flap arrangements (50, 51) are provided on the plurality of second air filter (17a, 17b) ends. All these flaps will be operated based on control logic. As shown in FIG. 1a and FIG. 2, the exhaust fans (15, 16) are mounted on the enclosure (2) of the air conditioning unit (1) located above the one or more evaporative heat exchangers (11, 12) during indirect cooling stages to exhaust the moist air through the secondary air passages of the one or more evaporative heat exchangers (11, 12) to the atmosphere. Speed of the exhaust fans (15, 16) can be varied accordingly and hence exhaust air quantity can be controlled by varying the input power to the fan motors by means of variable resistor which is in-built in the motors.

FIG. 1b illustrates the primary air and secondary air flow paths and the motorized flap positions during normal operation mode and severe operation mode of the air conditioning unit (1).

In normal mode of operation i.e., when cabin temperature is not more than ambient by 5°C, at least one motorized flaps (41, 42, 50, 51) are remained in closed condition, 100% of the cold air which is coming out from the air conditioning unit (1) is delivered to the cabin to be cooled. In this condition, since 100% of secondary air is being taken from the cabin (10) of the vehicle (49), the air temperature passing through the inclined or vertical channels of the one or more evaporative heat exchangers (11, 12) are lesser than the ambient temperature and this temperature would be sufficient to cool the non- woven web material on secondary channel surfaces (35). This non-woven web material is wet due to the water sprayed from the water dispensers (30, 31) at top. The primary air passing through the horizontal channels are sensibly cooled whereas secondary air in inclined or vertical channels is exhausted as hot and moist air to the atmosphere by exhaust fans (15, 16) mounted on top.

In severe mode of operation, i.e., if the vehicle is hot soaked under solar load, the cabin temperature may reach at least 5°C more than the ambient temperature. Primary cold air from the connecting roof ducts (6, 7) is partially diverted to the secondary air filters (17a, 17b) so as to keep secondary wall temperatures colder to have faster cooling down of primary air from atmosphere.

In an embodiment of the present disclosure, at least 20% of total primary cold air is passed through the plurality of connecting ducts (43, 44) to the secondary channels (37) of the one or more evaporative heat exchangers (11, 12) when the at least one motorized flaps (41, 42) (mounted on duct end) and (50, 51) (mounted on secondary air filters end) are in open position, alternatively referred as operating condition. The at least one motorized flaps (41, 42, 50, 51) are operated based on the control logic defined between cabin and ambient temperatures. The flaps remains in open condition until cabin temperature satisfies the logic defined in FIG. 8. It is also provided in the control logic that the exhaust fans (15, 16) remains in OFF condition until all flaps are closed.

FIG. 8 illustrates a Flow chart which explains the control logic to be followed to operate the at least one motorized flaps (41, 42, 50, 51) and exhaust fans (15, 16). As shown in the logic, if the cabin temperature is 5°C greater than the ambient temperature, the exhaust fans (15, 16) are switched off and the at least one motorized flaps (41, 42, 50, 51) are opened. The one or more blowers (4, 5) are switched ON to supply major amount of air approximately around 80% to the roof ducts (6, 7), and remaining amount of air approximately around 20% of air for secondary passage of the indirect cooling stage. Now, if the temperature drop between ambient and cabin is lesser than 15°C, the cycle is repeated from first, else the at least one motorized flaps (41, 42, 50, 51) are closed and the exhaust fans (15, 16) are turned ON to take away the moisture air to the atmosphere. The one or more blowers (4, 5) continue to run after ensuring the flaps are fully closed.

FIG. 9 illustrates a Flow chart which explains the control logic to be followed before switching on the one or more blowers (4, 5) in normal operation. The system is switched ON and the water level in the second water sump (19) is checked, if the water level is low, makeup water is added until maximum water level is reached. The water level in the first water sump (18) is checked, if the water level is low, makeup water in the first water sump (18) is added until maximum water level is reached. The direct cooling stage pump (29) is switched on for around 4 - 6 minutes preferably 5 minutes. The indirect cooling stage pump (28) is switched ON after 5 minutes. The at least one motorized flaps (41, 42, 50, 51) are closed and the exhaust fans (15, 16) are switched ON for 1 - 3 minutes preferably 2 minute to exhaust the hot cabin air out. The one or more blowers (4, 5) are switched ON to supply 100% air to the roof ducts (6, 7).

Control panel (45) is mounted in the driver zone to monitor the passenger cabin comfort condition and also for trouble shooting of the system (diagnostics). Driver can set the desired cabin temperature. Temperature sensors are provided inside and outside the cabin (10). Sensors provided in both first and second sumps (18, 19) to continuously verify the water level and shows an indicator on control panel (45) which is mounted at driver area. When the water level reaches to a minimum level there will be a reminder shown on control panel (45) to top up the make-up water.

FIG. 6 illustrates the primary air conditions undergoing different thermodynamic processes on a conventional psychrometric chart. Point 1 refers the primary filtered air condition before entering the indirect cooling stage. Point 2 refers the sensibly cooled primary air condition after indirect cooling stage where there is no moisture addition. Point 3 refers the adiabatically cooled primary air condition after direct cooling stage which is supplied to the roof ducts (6, 7).

FIG .4b illustrates the refrigerant circuit attached to the first water sump (18) as optional to supply chilled water to the indirect one or more evaporative heat exchangers (11, 12) as per the cabin cooling requirements. The refrigerant circuit consists of a compressor (52), condenser (53), expansion valve (54) and a chiller heat exchanger (55). A small sized compressor (52) is belt driven from the engine crank pulley. When refrigerant circuit is enabled by giving the request in a separate control panel, the chiller heat exchanger (55) which is submerged inside the first water sump (18) cools the surrounding water which is intended to supply for indirect cooling stages at the one or more evaporative heat exchangers (11, 12). The refrigerant circuit is best utilized during hot and humid ambient conditions. Direct cooling stages at the one or more evaporative pads (13, 14) (cooling and humidification) are disabled by switching of the water pump (29) and only indirect cooling stages (11, 12) (sensible cooling) are enabled to provide cooling for the cabin space without adding any moisture. Further efficiency of the air conditioning unit (1) is improved due to reduced power consumption since water pump (29) is off.

As explained a typical bus requires one or more air conditioning units (1), one for LH side passengers, another one for RH side passengers due to higher heat loads. A single air conditioning unit (1) can also be used in typical trucks, vans and any passenger cars or any moving vehicles with a single blower or multiple blowers along with compatible ducting arrangement.

In another embodiment of the present disclosure, multiple modules of air conditioning unit (1) can also be used in any moving vehicles including Fuel Cell bus where water is the end product as an outcome of chemical reactions. This water can be directly used as make up water for the said air conditioning unit (1).

Air conditioning unit (1) used in this disclosure is the system which removes the sensible heat from the cabin (10) and also maintains humidity levels up to acceptable range especially for hot and dry climatic conditions.

ADVANTAGES

Two stage evaporative systems in comparison to conventional single stage evaporative coolers can have more cooling capacity. These units do not use a refrigerant compressor and are thus significantly more energy efficient than conventional AC systems. The units add less moisture to the conditioned space and always work on fresh air there by providing better indoor environment and comfort of occupants. Further operating cost of these systems are far lesser than conventional refrigerant based AC systems due to absence of compressor. Since these units do not use any CFC. HCFC, HFC based refrigerants, provides 100% ozone safe. The cabin temperature can be dropped to 15°C and can be achieved within 10 minutes with respect to the ambient condition in normal mode of operation. Motorized flap arrangement helps in reducing cabin temperature by 20°C from ambient temperature within 10 minutes especially in a hot soak condition of the vehicle.

The air conditioning unit of the present disclosure improves the passenger comfort in the vehicle, even when the vehicle is in hot soaked condition.

The air conditioning unit of the present disclosure, has 10 % reduced operating noise when compared with that of the prior arts.

REFERRAL NUMERALS

Referral Numeral	Description
100	Automotive cabin environment management system
1	Air conditioning unit
2	Enclosure
3	First air filter
4, 5	Blowers
6, 7	Roof ducts
8, 9	Vents
10	Cabin
11, 12	Evaporative heat exchangers
13, 14	Evaporative pads
15, 16	Exhaust fans
17a, 17b	Second air filters
18	First water sump
19	Second water sump
20, 21, 22, 23	Auxiliary sumps
24, 25, 26, 27	Water filters
28, 29	Recirculating pumps
30, 31, 32, 33	Water dispensers
34	Cabin floor
35	Secondary channel surfaces
36	First passages
37	Second passages

38	Primary surface of Heat exchanger plates
39, 40	Water eliminators
41, 42, 50, 51	Motorized flaps
43, 44	Connecting ducts
45	Control panel
46, 47	Air guiders
48	Suction space
49	Vehicle
52	Compressor
53	Condenser
54	Expansion valve
55	Chill heat exchanger
56	Manual valve
57	Float

EQUIVALENTS

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation *is* explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean *at least* the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means *at least* two recitations, or *two or more* recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

WE CLAIM:

1. An automotive cabin environment management system (100) comprising:

an enclosure (2);

a first air filer (3) mounted on top of the enclosure (2), wherein the first air filter (3) is configured to draw atmospheric air;

one or more air conditioning unit (1) mounted within the enclosure (2), wherein the one or more air conditioning unit (1) receives atmospheric air via the first air filter (3) to generate conditioned air to be supplied to a cabin (10) of the vehicle (49);

plurality of second air filters (17a, 17b) are mounted below the enclosure (2), wherein each of the plurality of second air filters (17a, 17b) are located on either sides of the first air filter (3) and are fluidly communicably attached to one of the one or more air conditioning unit (1);

plurality of connecting ducts (43, 44), wherein each of the plurality of connecting ducts (43, 44) are connected to at least one of the plurality of second air filters (17a, 17b);

at least one motorized flaps (41, 42, 50, 51) are mounted within the each of the plurality of connecting ducts (43, 44), wherein the at least one motorized flaps (41, 42, 50, 51) are located away from the plurality of the second air filters (17a, 17b);

wherein the plurality of second air filters (17a, 17b), plurality of connecting ducts (43, 44) and at least one motorized flaps (41, 42, 50, 51) are arranged such that, the plurality of connecting ducts (43, 44) redirects predetermined volume of the conditioned air to be supplied to the cabin (10) back into the one or more air conditioning unit (1) via the plurality of second air filters (17a, 17b) when the at least one motorized flaps (41, 42, 50, 51) are in operating condition.

2. The automotive cabin environment management system (100) as claimed in claim 1, wherein each of the one or more air conditioning unit (1) comprises:

one or more evaporative heat exchangers (11, 12) of predetermined shape, wherein the one or more evaporative heat exchangers (11, 12) are configured in vicinity of the first air filter (3) to receive atmospheric air via the first air filter (3);

one or more evaporative pads (13, 14), wherein the at least one evaporative pad (13, 14) is placed adjacent to one or more evaporative heat exchangers (11, 12) and is configured to receive substantially conditioned air from the one or more evaporative heat exchangers (11, 12);

one or more blowers (4, 5) are placed adjacent to the one or more evaporative pads (13, 14), wherein the one or more blowers (4, 5) are configured to receive conditioned air from the one or more evaporative pads (13, 14) and supply the conditioned air into the cabin (10);

at least one exhaust fan (15, 16) placed above each of the one or more evaporative heat exchangers (11, 12), wherein the at least one exhaust fan (15, 16) expels hot air from the cabin (10) to the atmosphere;

at least one water dispenser (30, 31, 32, 33) placed above the each of the one or more evaporative heat exchangers (11, 12) and the each of the one or more evaporative pads (13, 14), wherein the at least one water dispenser (30, 31, 32, 33) is configured to dispense water onto the each of the one or more evaporative heat exchangers (11, 12) and the each of the one or more evaporative pads (13, 14);

at least one water eliminator (39, 40) placed adjacent to the each of the one or more evaporative pads (13, 14), wherein at least one water eliminator (39, 40) configured to eliminate the moisture from the conditioned air.

3. The automotive cabin environment management system (100) as claimed in claim 1 comprises plurality of air guiders (46, 47) located inside the each of the one or more air conditioning unit (1), wherein the plurality of air guiders (46, 47) are configured to guide the atmospheric air received via the first air filter (3) into the one or more evaporative heat exchangers (11, 12).

4. The automotive cabin environment management system (100) as claimed in claim 1 comprises plurality of roof ducts (6, 7) connected to the enclosure (2), wherein the plurality of roof ducts (6, 7) runs through substantial length of the cabin (10) for supplying conditioned air.

5. The automotive cabin environment management system (100) as claimed in claim 1 comprises a first water sump (18) provided below the cabin (10) of the vehicle (49) adopted to store water, wherein the one or more evaporative heat exchangers (11,12) of the one or more air conditioning unit (1) receives water from the first water sump (18).

6. The automotive cabin environment management system (100) as claimed in claim 1 comprises a second water sump (19) provided below the cabin (10) of the vehicle (49) adopted to store water, wherein the one or more evaporative pads (13, 14) of the one or more air conditioning unit (1) receives water from the second water sump (19).

7. The automotive cabin environment management system (100) as claimed in claim 1 comprises plurality of conduits (20, 21, 22, 23) provided at the bottom of each of the one or more evaporative heat exchangers (11, 12) and the one or more evaporative pads (13, 14) within the enclosure (2) for recirculating the water into the first water sump (18) and second water sump (19).

8. A method of managing an automotive cabin environment comprising steps of:

receiving atmospheric air into an one or more air conditioning unit (1) mounted within the enclosure (2) via a first air filter (3) for conditioning the atmospheric air;

redirecting predetermined volume of the conditioned air to be supplied to the cabin (10) of the vehicle (49) back to the one or more air conditioning unit (1) with the help of plurality of connecting ducts (43, 44), wherein the conditioned air is redirected via plurality of second air filters (17a, 17b) into the one or more air conditioning unit (1) for further conditioning;

wherein, conditioned air is redirected when at least one motorized flap (41, 42, 50, 51) configured within the plurality of connecting ducts (43, 44) is in operating condition.

9. The method of managing an automotive cabin environment as claimed in claim 8, wherein the at least one motorized flap (41, 42, 50, 51) is operated when the temperature of the cabin (10) is more than predetermined cabin temperature.

10. The method of managing an automotive cabin environment as claimed in claim 10, wherein the predetermined cabin temperature ranges from 25° C to 35°C.

11. A vehicle comprising an automotive environment management system as claimed in claim 1.

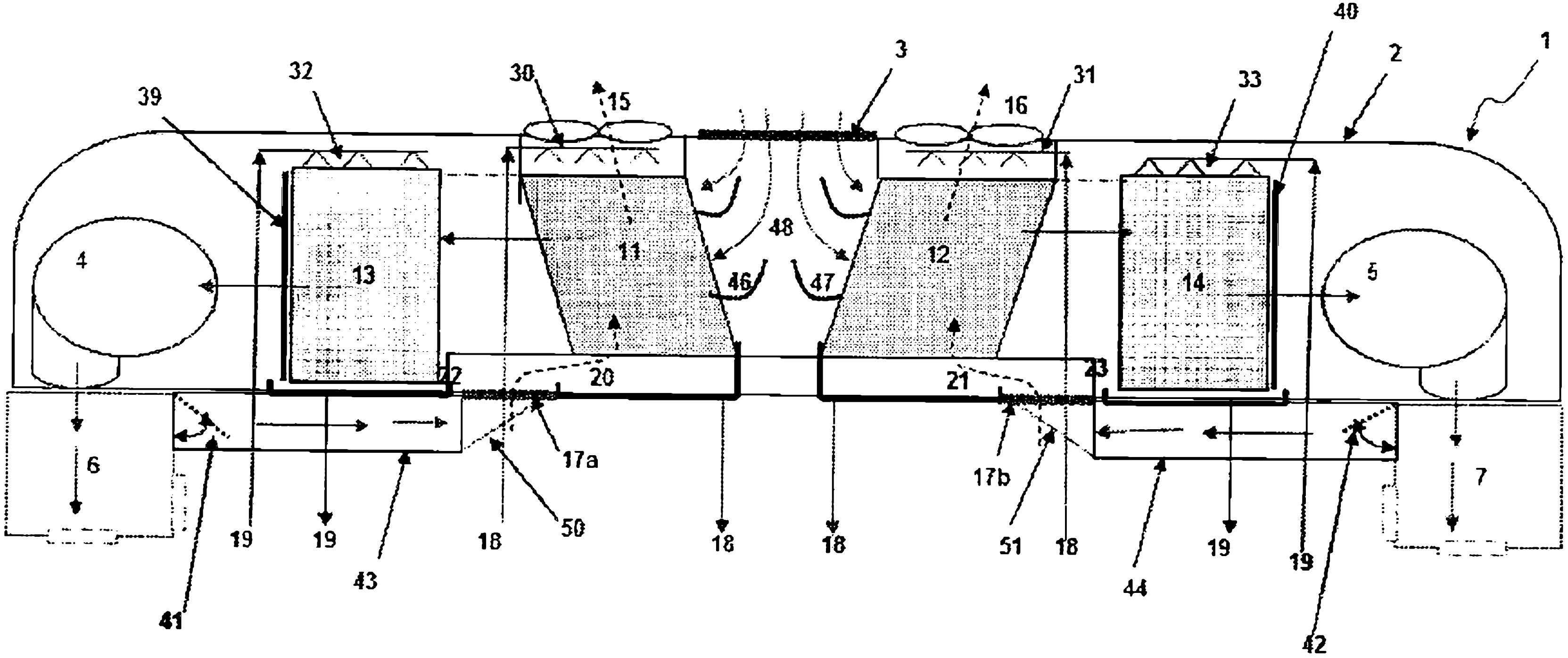
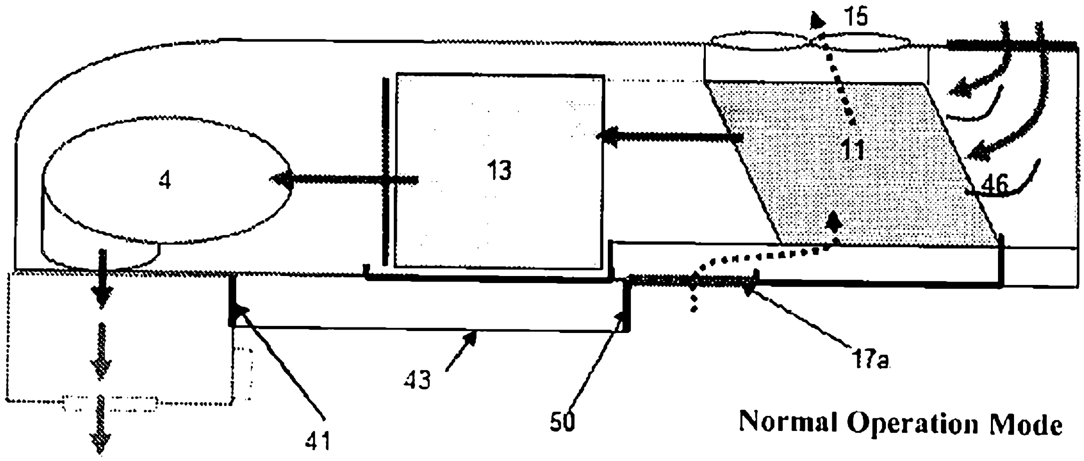

1
2
3
40
39
32
30
15
16
31
33
4
13
11
48
12
14
5
46
47
20
21
22
23
6
7
17a
17b
50
51
19
19
18
18
18
18
19
19
43
44
41
42

FIG. 1a

17247


15
11
46
13
4
17a
43
41
50
Normal Operation Mode

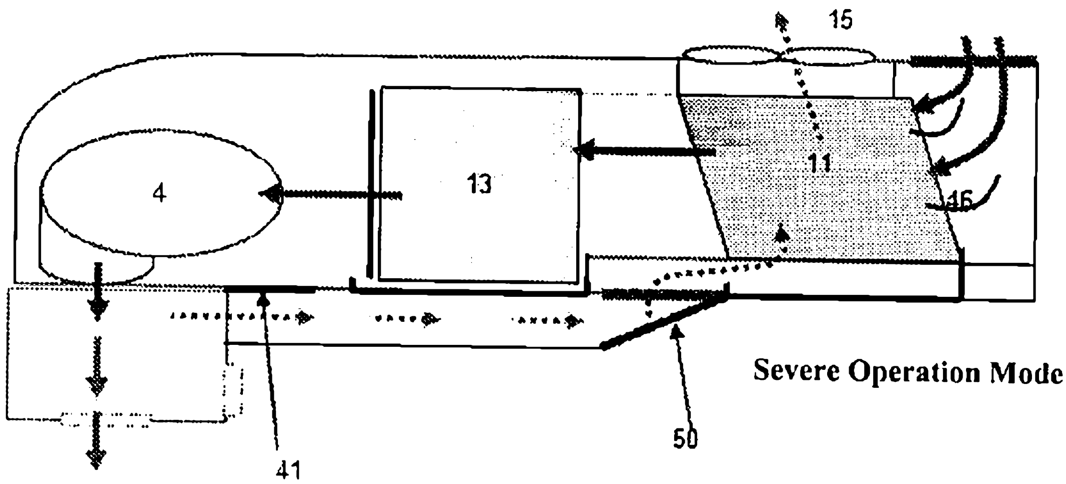

15
11
46
13
4
41
50
Severe Operation Mode

FIG. 1b

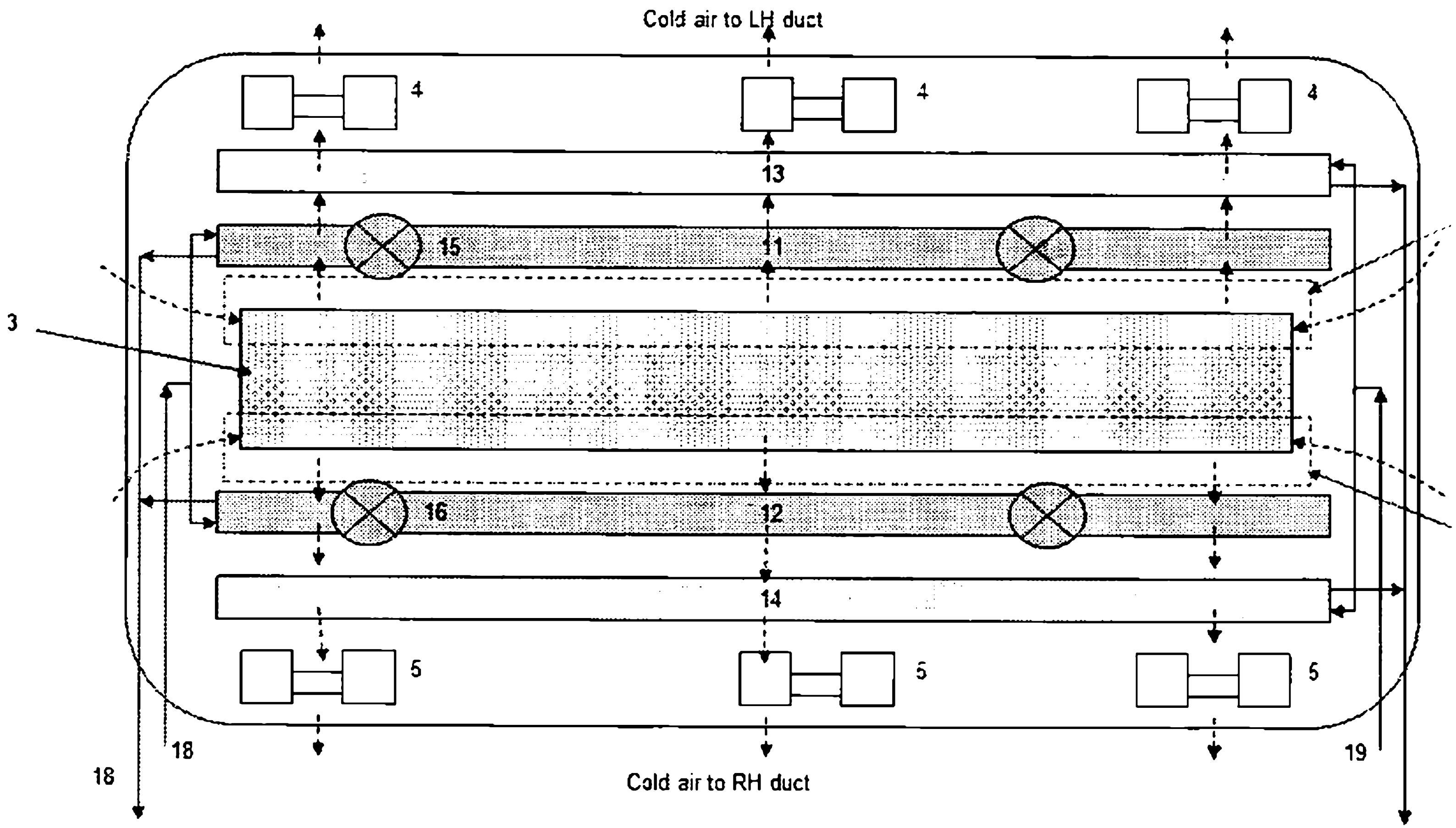

Cold air to LH duct
4
4
4
13
15
11
3
16
12
14
5
5
5
18
18
19
Cold air to RH duct

FIG. 2

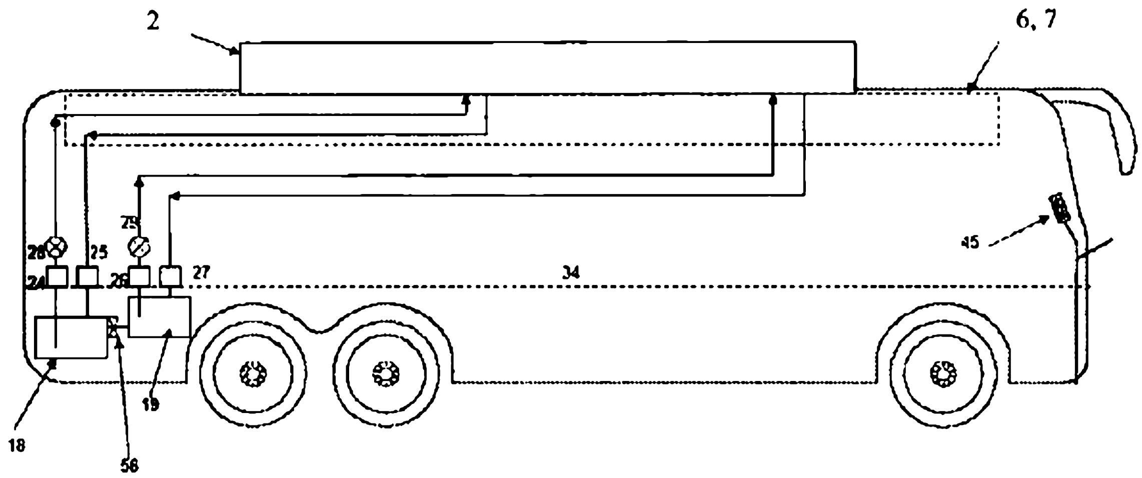

2
6, 7
28
24
25
26
29
27
34
45
18
19
56

FIG. 3

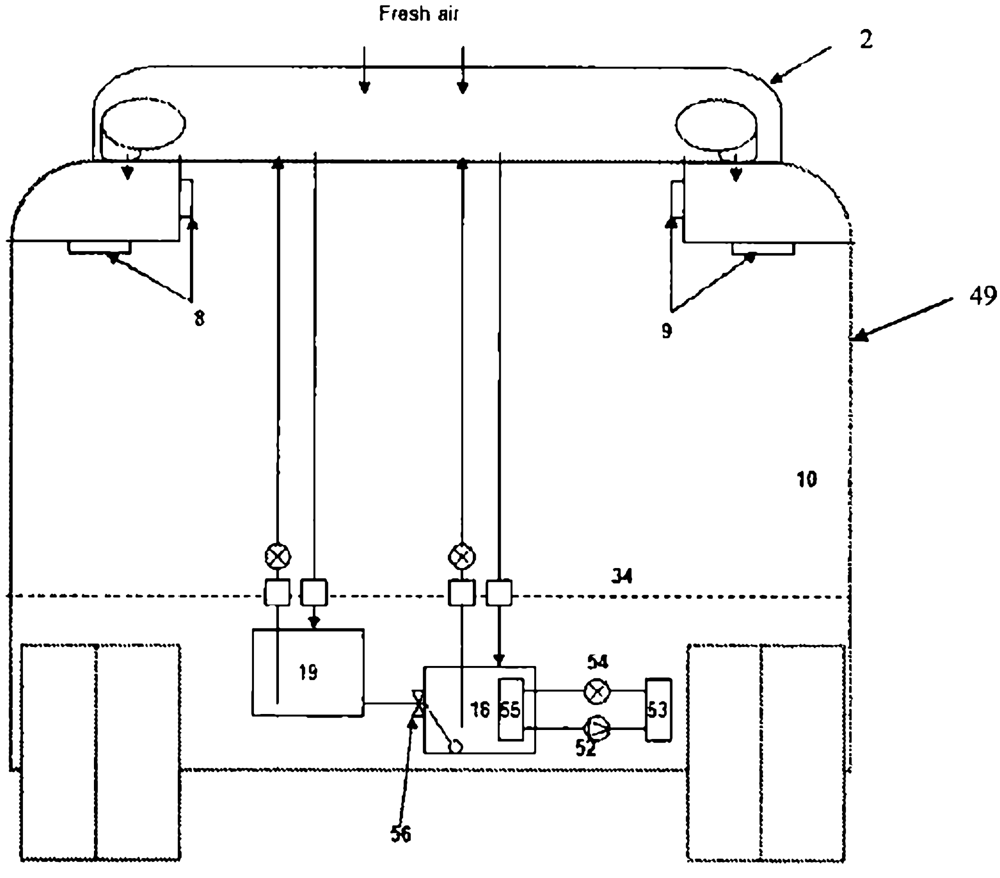

Fresh air
2
8
9
49
10
34
19
16
55
54
53
52
56

FIG. 4a

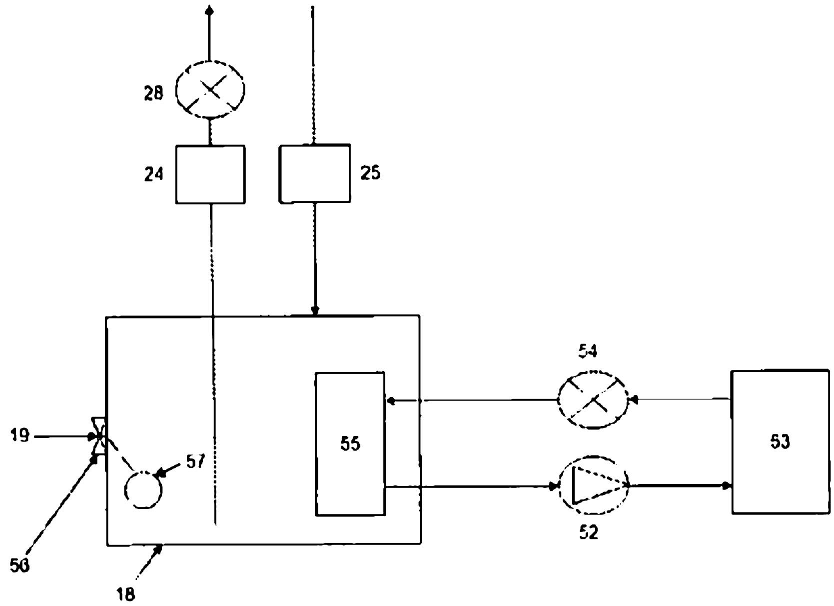

28
24
25
19
57
55
54
53
52
56
18

FIG. 4b

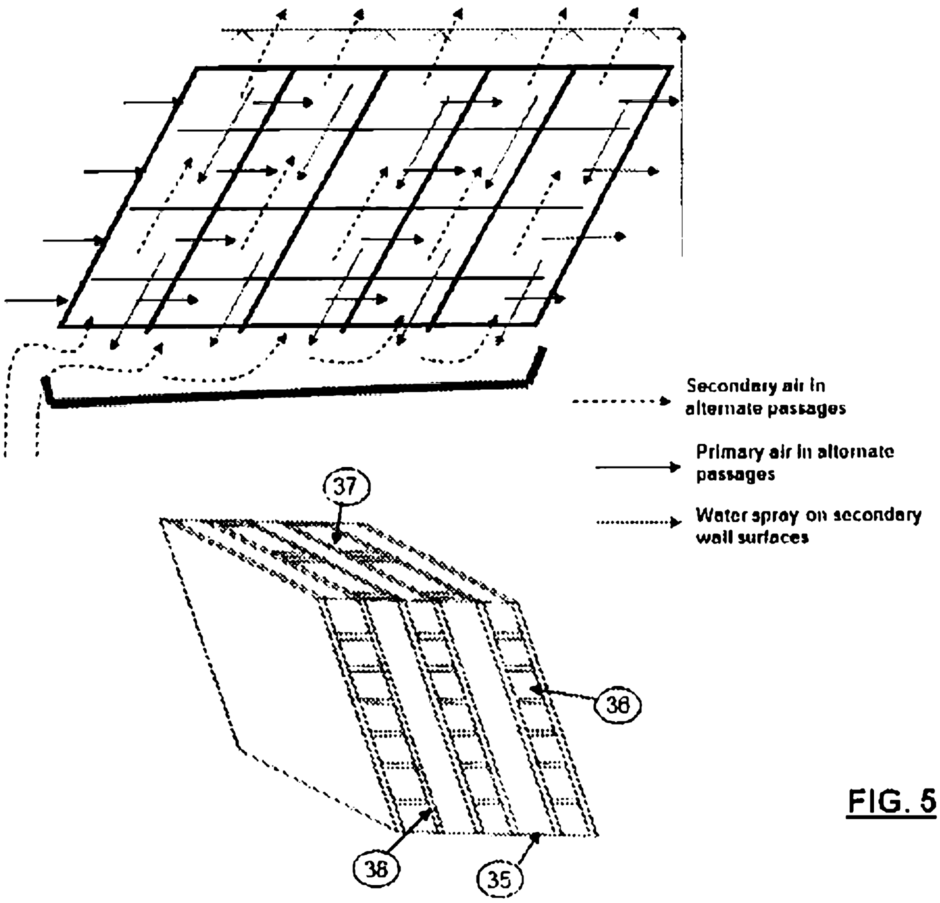

Secondary air in alternate passages
Primary air in alternate passages
Water spray on secondary wall surfaces
37
36
38
35

FIG. 5

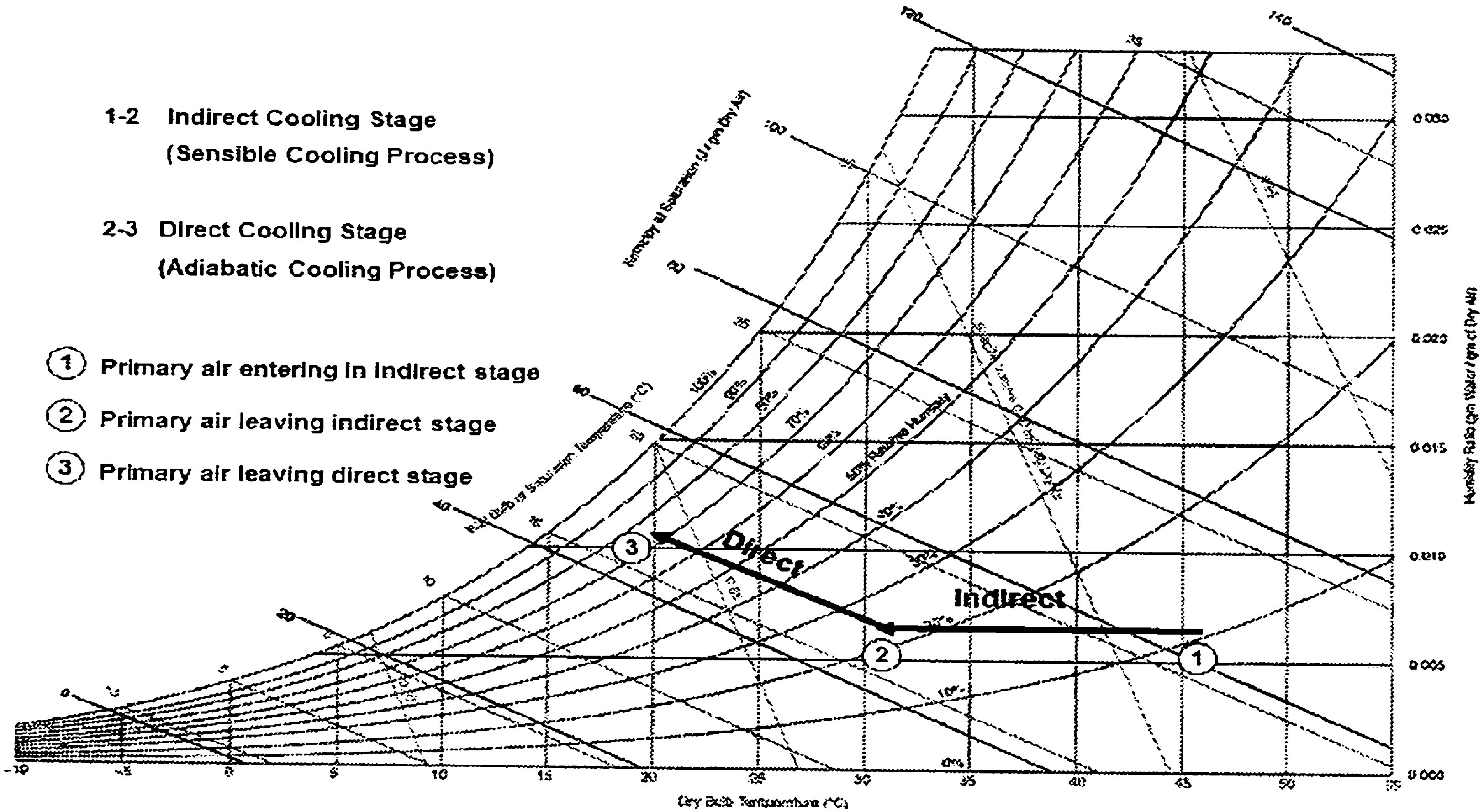

1-2 Indirect Cooling Stage
(Sensible Cooling Process)
2-3 Direct Cooling Stage
(Adiabatic Cooling Process)
1 Primary air entering in indirect stage
2 Primary air leaving indirect stage
3 Primary air leaving direct stage
Direct
Indirect
1
2
3
0.030
0.025
0.020
0.015
0.010
0.005
0.000
10
15
20
30
35
40
45
50

FIG. 6

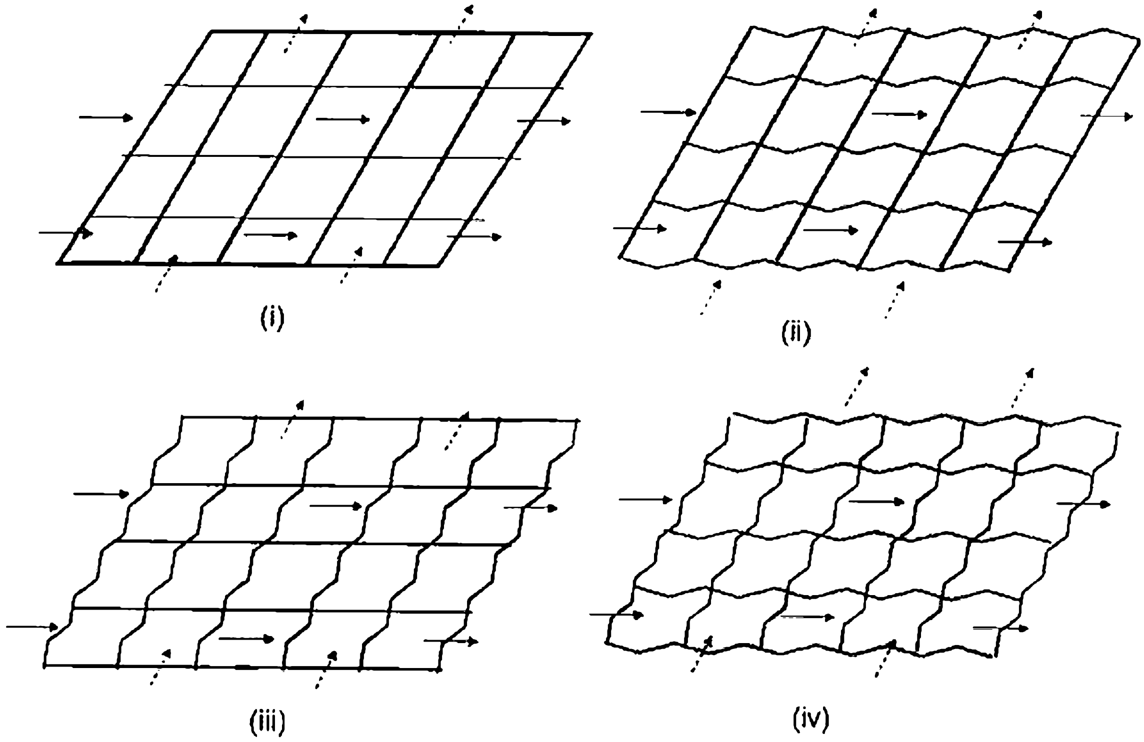


FIG. 7a

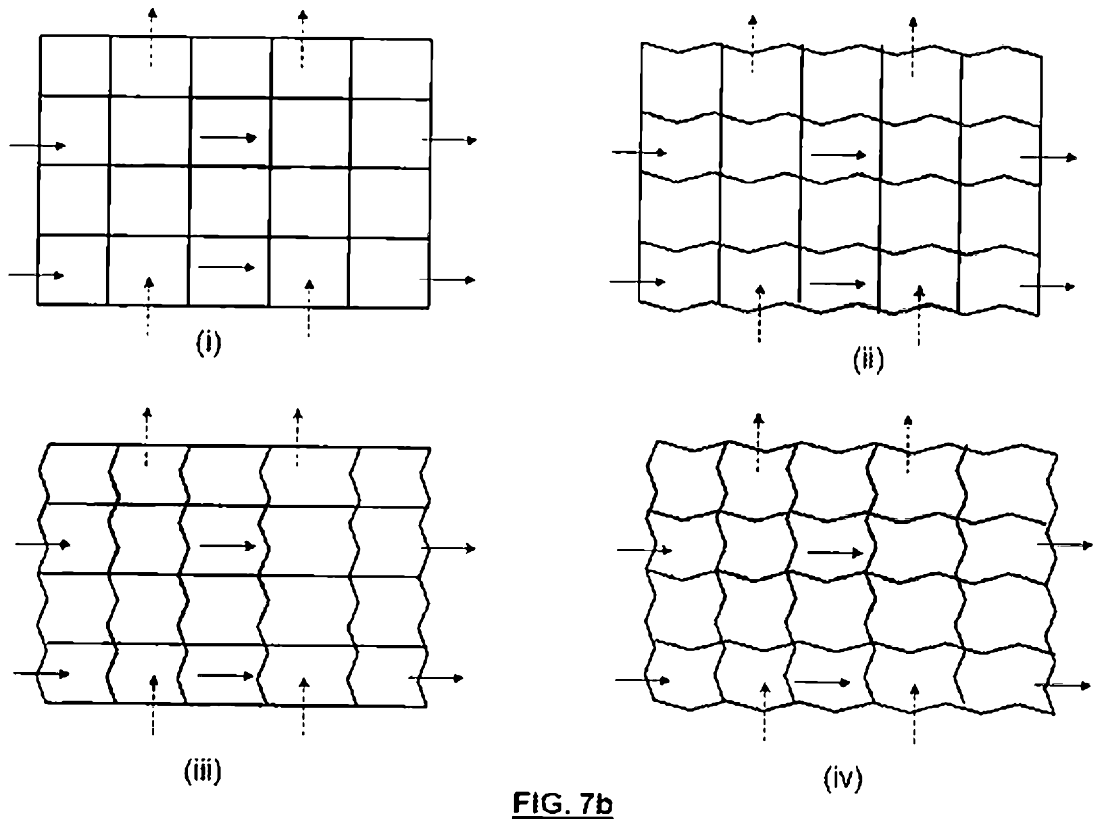


FIG. 7b

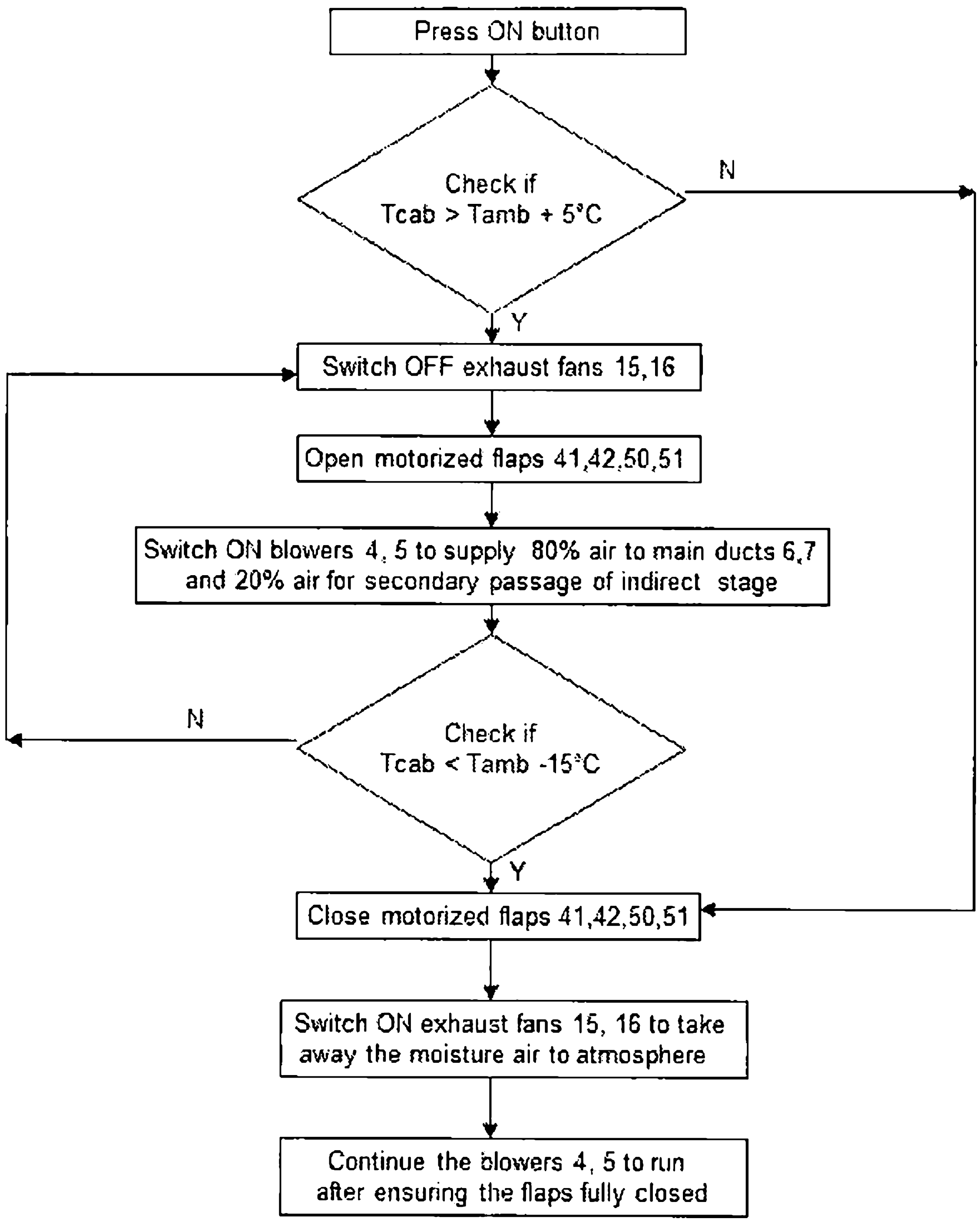

Press ON button
Check if
Tcab > Tamb + 5°C
N
Y
Switch OFF exhaust fans 15,16
Open motorized flaps 41,42,50,51
Switch ON blowers 4, 5 to supply 80% air to main ducts 6,7
and 20% air for secondary passage of indirect stage
Check if
Tcab < Tamb -15°C
N
Y
Close motorized flaps 41,42,50,51
Switch ON exhaust fans 15, 16 to take
away the moisture air to atmosphere
Continue the blowers 4, 5 to run
after ensuring the flaps fully closed

FIG. 8

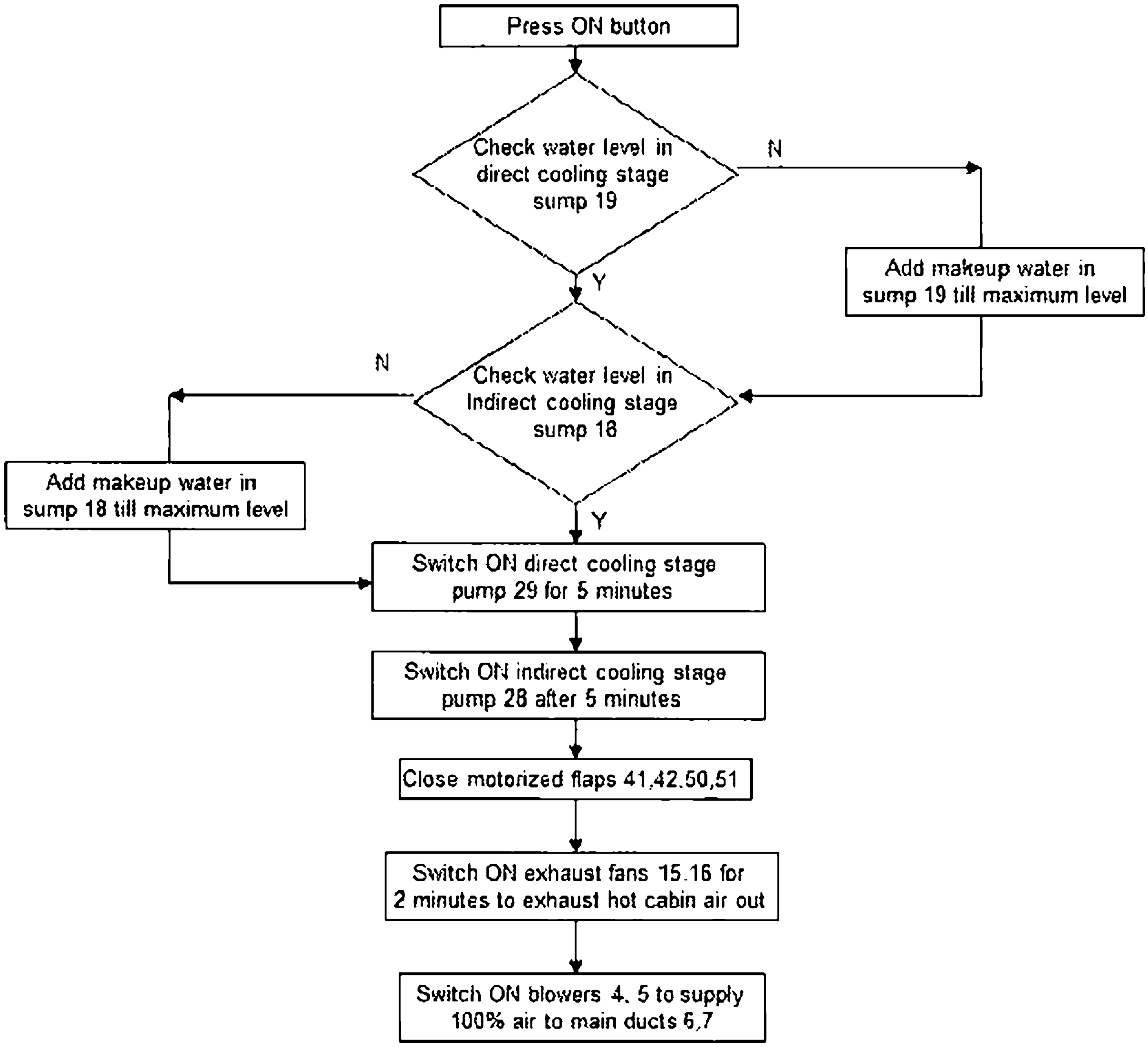

Press ON button
Check water level in direct cooling stage sump 19
N
Add makeup water in sump 19 till maximum level
Y
Check water level in Indirect cooling stage sump 18
N
Add makeup water in sump 18 till maximum level
Y
Switch ON direct cooling stage pump 29 for 5 minutes
Switch ON indirect cooling stage pump 28 after 5 minutes
Close motorized flaps 41,42.50,51
Switch ON exhaust fans 15.16 for 2 minutes to exhaust hot cabin air out
Switch ON blowers 4. 5 to supply 100% air to main ducts 6,7

FIG. 9